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NOVA Sco 2001 (V1178 SCO) ⋆

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Abstract. We present intermediate resolution spectroscopy and near infrared photometry of NOVA Sco 2001 (V1178 Sco), which was first detected May 13th 2001 and reported June 21th 2001, and obtained by us the same day. We also retrieved very accurate astrometry of the target in this very crowded field. This is needed to be able to do follow up observations of the postnova during the next years. The spectrum shows an overall expansion of 2100 km s^{-1} and has clearly complex, and most likely nonsymmetric, outflow substructures. We clearly identify this object as classical nova, "Fe II" subclass.

Key words. stars: novae - stars: individual: NOVA Sco 2001 = V1178 Sco

1. Introduction

NOVA Sco 2001 was discovered May 13th 2001 as a $10\overset{m}{.}5$ object and reported first June 21th 2001, 18:03 UT (Hasada et al. 2001). Liller (2001) reports there also first spectroscopic results at low dispersion, confirming a strong H_α line. The variable star name given to the object is V1178 Sco (Samus & Kazarovets 2001). We obtained near infrared images in the Gunn-i, J and K_s band using the DENIS survey instrument (Epchtein et al. 1997) attached to the ESO/LaSilla 1m telescope using $5\overset{m}{.}2$ attenuating filters (June 21th 2001, 23:12 UT). The spectrum was taken using the Danish 1.5m telescope at LaSilla (June 22th 2001, 02:46 UT) with the DFOSC mounted. Also a red continuum filter image was obtained there. This filter was selected to have a largely line emission free narrow band image, to get best possible astrometry without effects of color shifts and differential refraction of the surrounding astrometric calibration sources.

2. Astrometry and Cross–identification

To obtain a very accurate astrometry of the target a DFOSC narrow band image was taken. To avoid displacements of sources due to different colors as seen normally in wide band filters, the red continuum filter ESO#840 centered at 683.82 nm and having a FWHM of 8.09 nm was used. The DFOSC is currently equipped with a MAT/EEV 44-82 2k×4k CCD giving, according to the manual, a resolution of $0\overset{''}{.}39$ per pixel. In fact we measure $0\overset{''}{.}39556 \pm 0\overset{''}{.}00018$. The FWHM on the images was $1\overset{''}{.}66$. As only half the chip is used the field of view is $13 \times 13'$. We used only the central part of the image with a radius of $1'$ around the target. This provides us with a highly distortion free image. Astrometric calibrators were taken from *USNO CCD Astrometric Catalogue* (UCAC) (Zacharias et al. 2000). This catalogue contains southern sources with an accuracy of about 20 mas in the red magnitude range $10^m < m < 14^m$ and still has an accuracy of about 70 mas at the limit of 16^m. We used 6 stars surrounding the target to obtain the astrometry (Tab. 1). One source corresponds to a TYCHO-2 source. The difference of the position in the 2 catalogues is, after correction for proper motion, approximately 25 mas in both coordinates.

Table 1. Astrometric calibration stars

UCAC Id.	TYCHO-2 Id.	α (J2000.0)	δ (J2000.0)
19383082	1837251	269.3048774	-32.4037892
19383048		269.2938362	-32.3957092
19383013		269.2828100	-32.3929684
19383009		269.2820474	-32.3899953
19382967		269.2719486	-32.3779859
19382986		269.2773877	-32.3915264

The source extraction on the image was obtained by using SExtractor v2.1.6 (Bertin & Arnouts 1996). The rms of the positions, using a plane astrometry without distortion coefficients, was 41 mas. The 2 largest residuals (up to 71 mas) are found for the two faintest sources. As our S/N was very high even for those sources, we assume that

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⋆ Based on observations made with the Danish 1.5-m telescope and the 1.0-m telescope at ESO, La Silla Chile

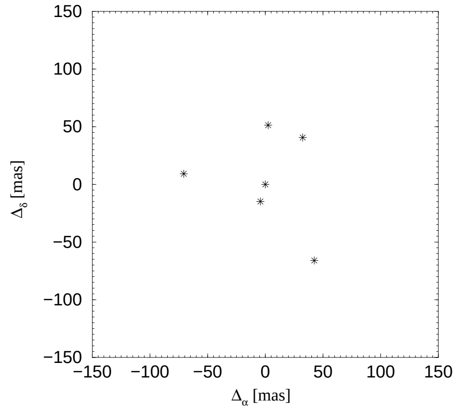

Fig. 1. The scatter diagram of the astrometric calibration sources around the target.

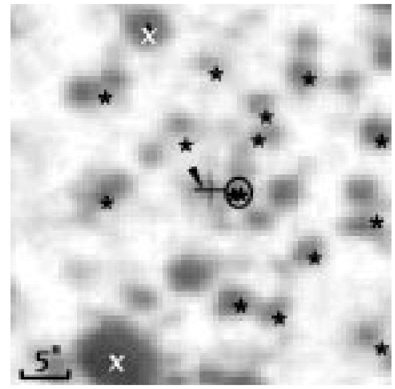

Fig. 2. The finding chart for the target from the CDS/Aladin MAMA CAI red scan. The coordinates from the astrometry are centered (fineline cross). We assume that the faint star marked with the arrow is the real progenitor. The UNSO A2 sources (asterix) and the UCAC sources (×) are marked. The USNO sources 0523-30816527 and 0525-30186320, being identical with the 2MASS source 1757066-322305 (circle), are definitely not the progenitor(s) (see text).

part of this error originates from the UCAC. These residuals are in the order of magnitude for the input catalogue itself. The $1{\times}1'$ region was thus sufficent. It would give us just uncertainties due to distortion increasing the field. As the target is very bright, we assume the accuracy of our coordinates to be 40 mas.:

$$\alpha_{\mathrm{J2000.0}} = 17^{\mathrm{h}}57^{\mathrm{m}}06\overset{\mathrm{s}}{.}922 \pm 0\overset{\mathrm{s}}{.}003$$
$$\delta_{\mathrm{J2000.0}} = -32°25'05\overset{''}{.}03 \pm 0\overset{''}{.}04\ .$$

An inspection of the sky survey plates SERC V (1987.590 and 1987.708) and 2$^{\mathrm{nd}}$ ed. Equatorial red (1989.674 and 1992.421) shows a source, which is significantly fainter than the red $17\overset{\mathrm{m}}{.}5$ source stated in Hasada et al. (2001). Although this source is faint, we are able to state that there is no variability at a level of $0\overset{\mathrm{m}}{.}25$ at those epochs. The CAI MAMA scans provided at CDS give an estimate of B$\leq 20\overset{\mathrm{m}}{.}5$ and R$\leq 18\overset{\mathrm{m}}{.}2$ when using the PSF fitting for decrowding and photometric calibration as described in Kimeswenger & Weinberger (2001). The DENIS $\mathrm{K_s}$ images were used together with the accurate astrometry above, to carefully cross–identify the 2MASS sources of the region. We thus are able to definitely exclude the next nearby source 1757066-322305 as possible progenitor. This source is westward to the target still visible on the $\mathrm{K_s}$ images. Fig. 2 shows, that the two USNO A2 sources mentioned by Masi (2001) (0523-30816527 and 0525-30186320, one star in fact only) are the same source as the 2MASS source mentioned above. It has a significant offset to the target. The coordinate offset of Masi may originate from the fact that this target, observed from Italy, had a high airmass. He underestimated the effects of differential refraction when comparing his unfiltered CCD image with the USNO red. Queries to different public archives at e.g. ESO, ING, etc. gave no results concerning an earlier CCD image.

3. NIR Photometry

The near infrared photometry was obtained at the DENIS survey instrument (Epchtein et al. 1997) attached to the ESO/LaSilla 1m telescope. We used a Gunn-i ($\lambda_{\mathrm{eff}} = 0.81\ \mu$m) a standard J ($\lambda_{\mathrm{eff}} = 1.25\ \mu$m) and a $\mathrm{K_s}$ ($\lambda_{\mathrm{eff}} = 2.15\ \mu$m) filter. The night was photometric. The standard observations were taken from the survey run. The calibration was not done via the survey pipeline but manually. The methods are similar to those described in Cioni et al. (2000) and Fouqué et al. (2000). As the source was just below overexposure in normal survey mode, also images using a $5\overset{\mathrm{m}}{.}2$ attenuating filter set were obtained. The calibration of those sets is described in Kimeswenger et al. (2001). Thus in total 10 frames, taking the source at different positions of the detector, were obtained. This was done to minimize effects due to flatfield features and detector flaws.

Table 2. The results of the NIR photometry

Date	Band	[mag]	error
June, 21$^{\mathrm{th}}$ 2001, 23:12 UT	Gunn-i	$9\overset{\mathrm{m}}{.}75$	$0\overset{\mathrm{m}}{.}03$
	J	$8\overset{\mathrm{m}}{.}67$	$0\overset{\mathrm{m}}{.}05$
	$\mathrm{K_s}$	$8\overset{\mathrm{m}}{.}01$	$0\overset{\mathrm{m}}{.}04$

The colours (i-J = $1\overset{\mathrm{m}}{.}08$; J-$\mathrm{K_s}$ = $0\overset{\mathrm{m}}{.}66$) are completely different from those derived for e.g. CI Aql during the 2000 outburst at a date of about 30 to 40 days after discovery using the same instrument. While the i-J is significantly redder than the value obtained there, the J-$\mathrm{K_s}$ is significantly bluer. This may be an indicator of a less dominant Br_γ emission.

4. Spectroscopy

The spectra were obtained at the Danish 1.5m telescope at ESO LaSilla/Chile with the DFOSC spectrograph. We were using Grism #7, giving a resolution of 0.145 nm/pixel and a usable range from 450 to 680 nm. The calibration (bias, flatfield, wavelength calibration and response curve) was done using usual procedures in MIDAS and the calibration data given in the DFOSC manual. The absolute

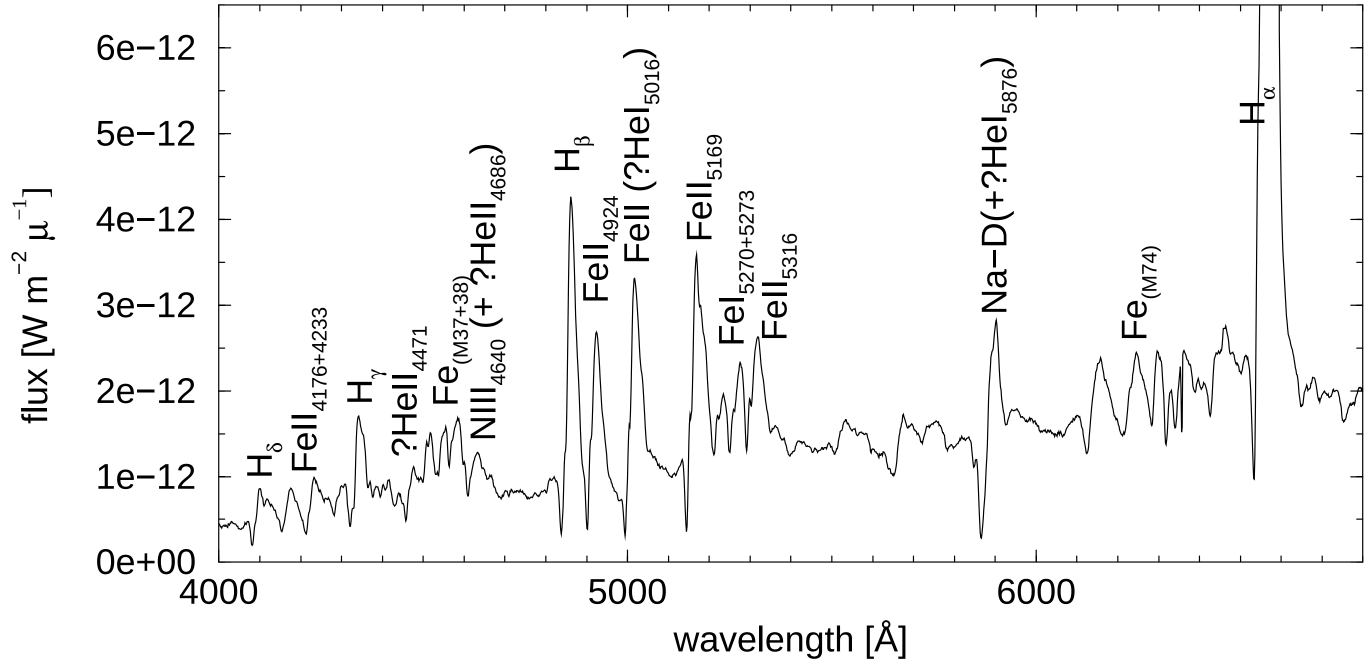

Fig. 3. The spectrum of V1178 SCO. H_α is displaced exceeding the box in order to see all the weaker features. The peak is 2.8 10^{-11} W m^{-2} μm^{-1} (12.7 × the red continuum). All P-Cygni profiles show more or less the same substructures. The maximum expansion velocity is about 2100 km s^{-1}. The slope of the continuum is consistent with the outburst having an age of more than one month. Series of Fe II lines are identified by their multiplet numbers only.

scale was calibrated by using the photometry of Liller (2001) and the standard V filter curve. The spectrum has a S/N of >200 in the continuum over the whole region.
As P-Cygni profiles we are able to identify the Balmer series from H_α to H_ϵ, FeII $\lambda\lambda$4176, 4233 and 5169. The high excitation lines NIII $\lambda\lambda$4640/HeII $\lambda\lambda$4686 do not appear in this nova. Remarkably, the iron lines are stronger than e.g reported in CI Aql (Kiss et al. 2001), while [NII] $\lambda\lambda$5755 does not appear at all. The Na-D line is very prominent too. Normally blended by HeI $\lambda\lambda$5876, this line appears here only as a weak absorption feature at the blue end.

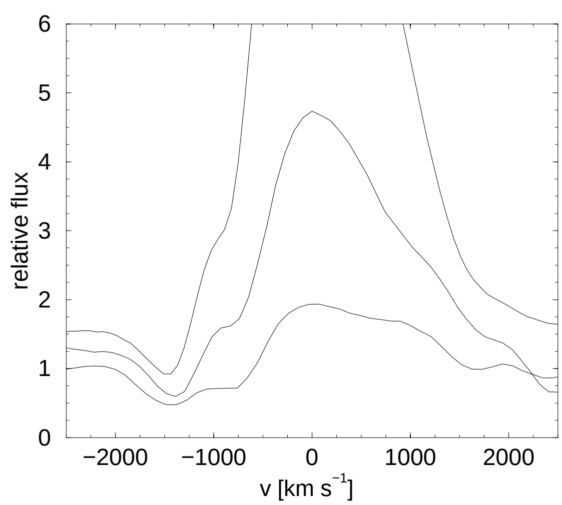

Fig. 4. The P-Cygni profile of the Hydrogen Balmer lines. From top to bottom: H_α, H_β and H_γ; the lines are normalized to local continuum and shifted by 0.25 each (see text).

The profiles of the Balmer serie lines are widely identical, providing a V_{max} of 2100 km s^{-1} and two nearly symmetrical features at about 900 km s^{-1}. The relative strength of this feature, both in emission as in absorption increases to higher levels. This is an indication for an inner shell not being in thermal equilibrium.

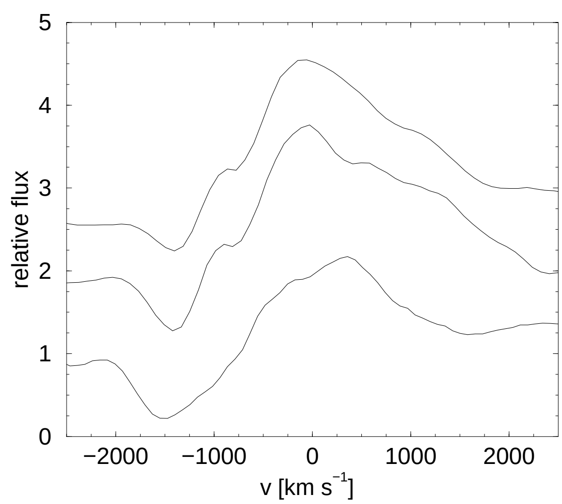

Fig. 5. The profiles of (from top to bottom) line at $\lambda\lambda$5014–5017 (Fe $II_{(M42)}$, HeI ?), FeII $\lambda\lambda$5169 and Na-D; the lines are normalized to local continuum and shifted by 1.0 each (see text).

While the structure of the line centered at 5014–5017 Å ($FeII_{(M42)}$, HeI ?) follows mostly that of the hydrogen lines (only V_{max} is lower), the other iron and the sodium lines show much more complex features. The emission maximum is even suppressed by some absorption in case of the Na-D line.

5. Conclusion

The spectrum allows us to classify this object, first called as "novalike variable" in some IAUCs, to be a classical nova of "Fe II" subtype (after Williams 1992). The astrometry presented here clearly indicates, that the progenitors discussed in the first IAU circulars are not the correct identifications. This will allow detailed followup after the decline. The outburst here, reaching $\geq 9^{\mathrm{m}}$ is clearly stronger than that of the recent events of CI Aql or V445 Pup. As the discovery was reported with a delay of about one month, we are unable to give colors and accurate photometry of the early phases of the event. Thus the t_1 date will be poorly defined. The blue NIR photometry suggests t_2 is not reached already. This makes it to be a moderately slow nova. Following the discussion in Kiss et al. (2001), one may obtain an absolute magnitude of $-7\overset{\mathrm{m}}{.}0 < M_V < -8\overset{\mathrm{m}}{.}0$. As we have no information about the interstellar reddening in this direction, we used the mean extinction method given for Miras and AGB stars in Whitelock et al. (2000). This leads to a crude distance estimate of 3 kpc and $\mathrm{A}_V \approx 6^{\mathrm{m}}$. This is in agreement with the possible progenitor on the plates to be a late K or early M giant.
The spectroscopy clearly shows a complex structure of the outflow. The velocity field obtained by the hydrogen and helium lines suggest a two shell structure similar to the models of Hanuschik et al. (1993). The metal lines even indicate a more complex, most likely non–symmetric outflow with respect to the line of sight.

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